

- (21) Application No 7918410  
 (22) Date of filing 25 May 1979  
 (23) Claims filed 25 May 1979  
 (30) Priority data  
 (31) 25334/78  
 79/10746  
 (32) 31 May 1978  
 27 Mar 1979  
 (33) United Kingdom (GB)  
 (43) Application published  
 20 Feb 1980  
 (51) INT CL<sup>3</sup>  
 F28F 1/12  
 B23D 25/12  
 (52) Domestic classification  
 F4S 2B12 2B4 2B5 4E1A  
 4F1  
 B3E 10E3 14G 1H4 1Y 5G  
 5Y NA  
 B3W 10F20U 10FY  
 10M20U 10MY 22 25 55A  
 (56) Documents cited  
 GB 1535561  
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 GB 1326774  
 GB 648829  
 GB 582142  
 (58) Field of search  
 F4S  
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(54) Heat exchangers

(57) Secondary surface heat exchange elements (attached e.g. to tubes 50, Figure 1 or 31, Figure 7) are arranged with louvres or other inclined surfaces which lie along planes inclined to the general direction A of fluid flow over the elements.

In Figure 2 the elements have mutually inclined V-shaped portions 54, 55 with louvres 56, 57 formed in the flanks of the V. The louvres are in sets and are inclined to the planes of the flanks and in opposite directions on each flank.

In Figures 4A and 7, each element

comprises side-by-side corrugated strips 11, 12, 13 joined together at the crests 17. The flanks of the corrugations are inclined to the general direction A of flow of medium over the element and the strips are laterally displaced from one another.

Apparatus for making the element consists of rolls (20, 21 Figures 8, 9) with teeth thereon which intermesh and are shaped to form the elements from sheet material (eg metal foil) fed between said rolls. Each roll is made of laminae angularly displaced from each other about the axis of the roll.

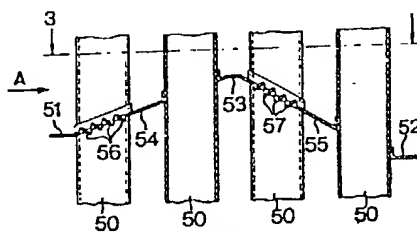


FIG. 2

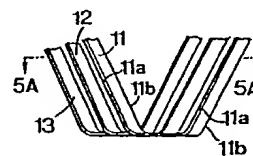


FIG. 4A

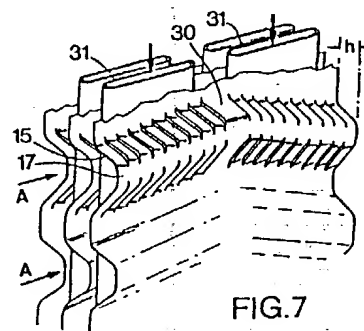


FIG. 7

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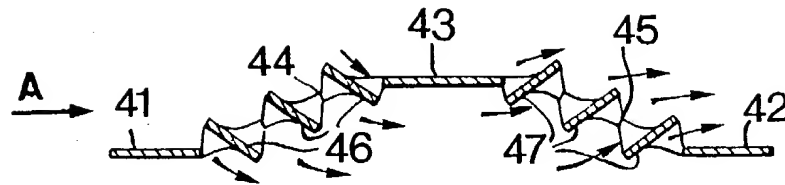


FIG. 1

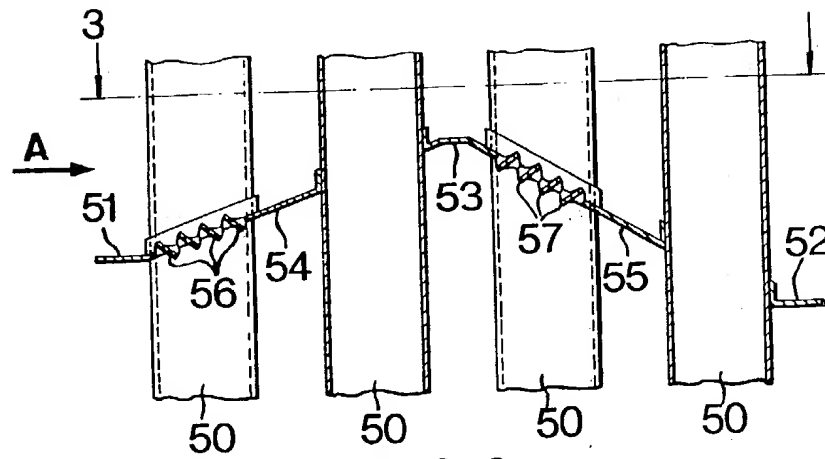


FIG. 2

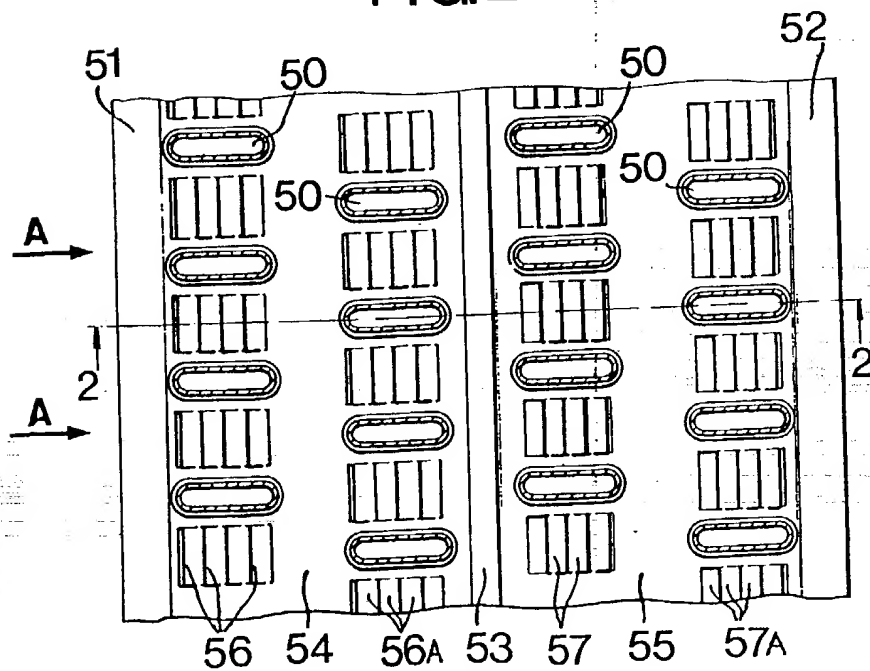


FIG. 3

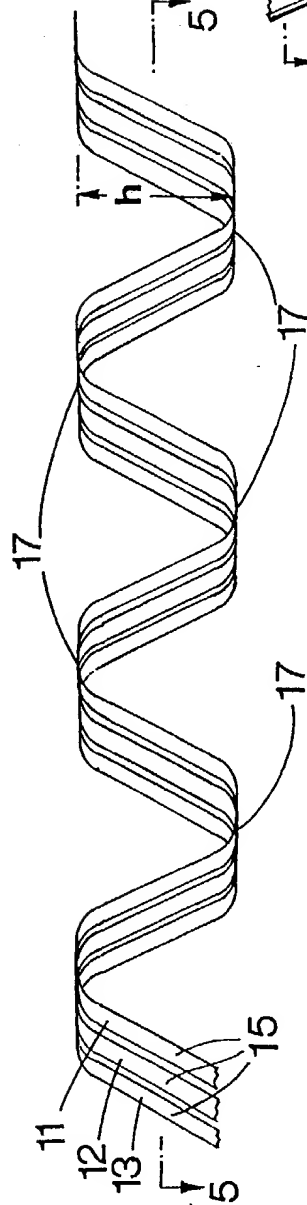


FIG. 4

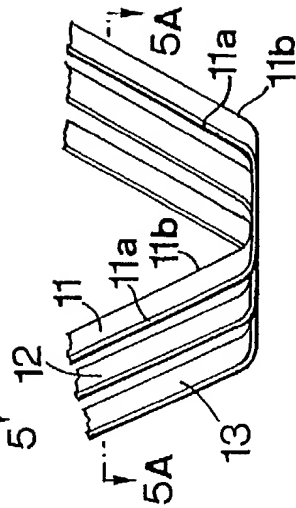


FIG. 4A

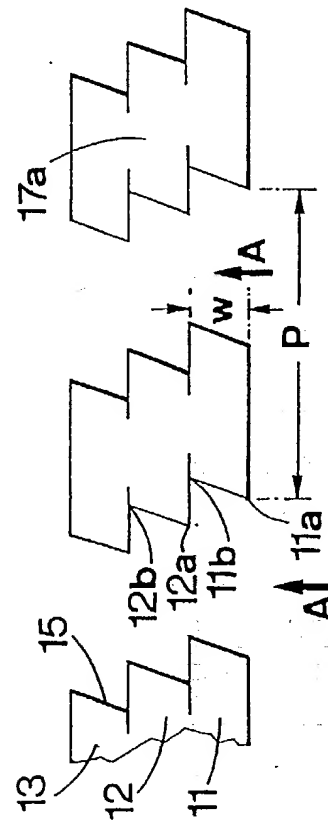


FIG. 5

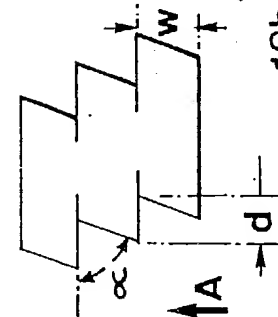
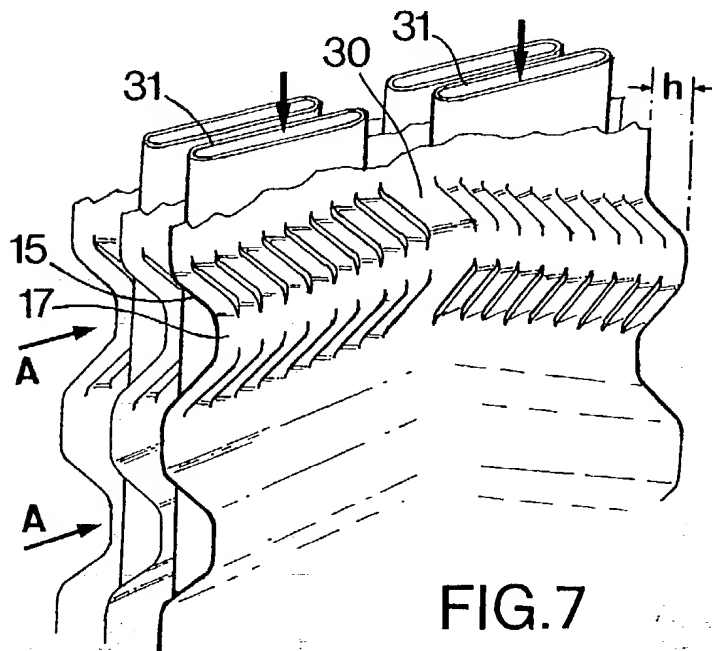
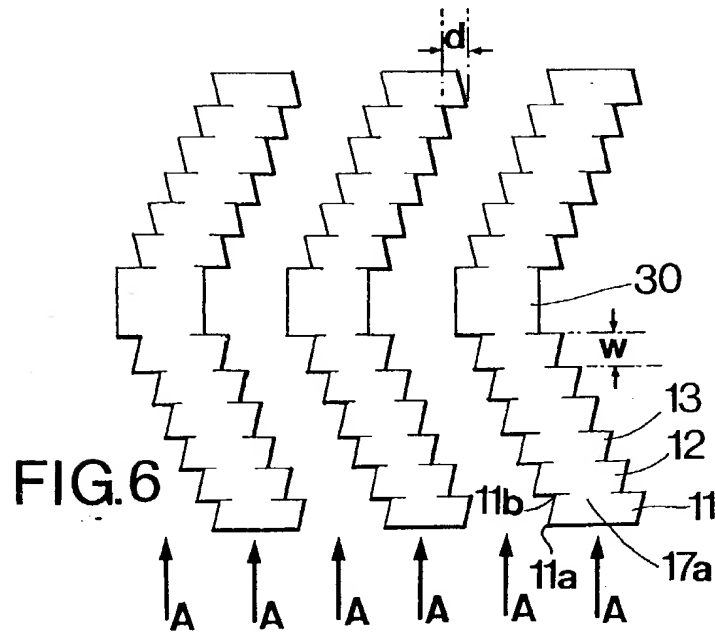


FIG. 5A

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4/4

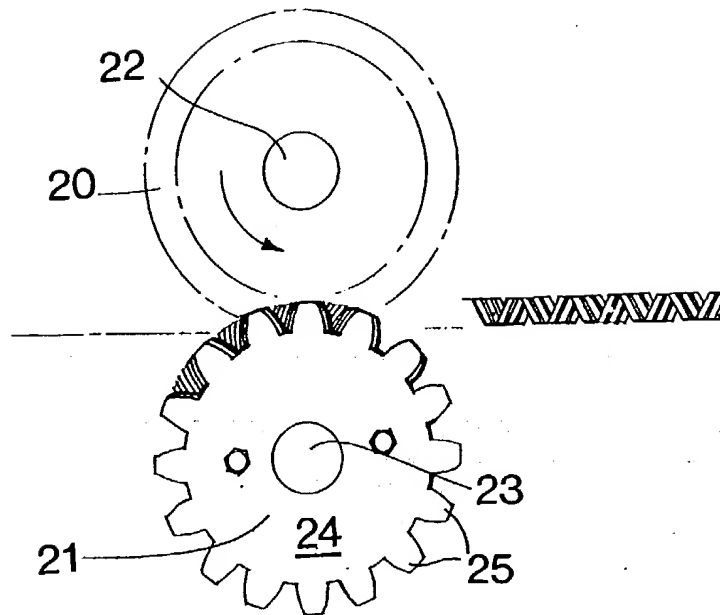


FIG. 8

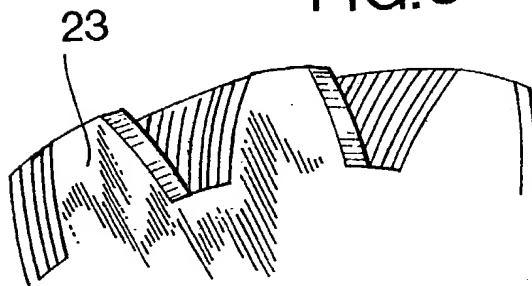


FIG. 9

## SPECIFICATION

## Heat Exchangers

- 5 This invention relates to heat exchangers and in particular to secondary surface elements for heat exchangers.

Louvered sheet material is already known for use in heat exchangers and the material may take several forms, such as in a fin and tube heat exchanger in which the tubes pass through apertures in a plurality of secondary surface fins. Corrugated sheet material is also used in which such material is located between tubes and louvers are formed in the flanks of the corrugations. In such arrangements the louvers are inclined or twisted relative to the plane of the associated sheet and gaps are formed in the material through which heat exchange medium can pass.

- 20 There has also been proposed in our British patent application No. 6608/77 17/12/79 corrugated sheet material in which there is formed a plurality of side by side strips which are displaced from one another in their longitudinal direction so that the surfaces of the strips lie in planes generally perpendicular to said longitudinal direction and the edges of the strips are exposed to heat exchange medium passing over the material.

The various known forms of secondary surface elements for heat exchangers suffer from disadvantages either in relation to their heat exchange properties, or their ease of manufacture, or both, and it is an object of the invention to provide secondary surface elements which have good heat exchange characteristics and are relatively straightforward to make.

- According to one aspect of the invention a secondary surface element for a heat exchanger comprises sheet material formed with successive mutually inclined integral portions, each arranged to be inclined to the general direction of flow of heat exchange medium over the elements and the mutually inclined portions having louvers formed therein, each louver lying in a plane inclined to the plane of the associated portion of the element. The louvers should be inclined at less than a right angle to the general direction of flow.

Preferably the sheet material is formed in successive V-shaped portions, the louvers being formed in the flanks of the V and lying in planes inclined to the flanks of the V.

- According to another aspect of the invention a secondary surface element for a heat exchanger comprises corrugated sheet material formed of a plurality of corrugated strips, each strip being similarly shaped and corresponding portions of the flanks of the corrugations in adjacent strips being displaced from one another in the longitudinal direction of the strips whereby the leading edge of each flank is displaced in one direction from the trailing edge of the corresponding flank of an immediately adjacent strip, the strips being joined to one another to form a unitary structure, and the flanks of the corrugations each being inclined in the opposite direction to said displacement at an acute

angle to the longitudinal direction of the strip.

- According to a further aspect of the invention apparatus for forming the secondary surface element comprises a pair of rolls and drive means for driving at least one of the rolls so that the rolls rotate in opposite directions, each roll being formed of a set of laminae arranged side by side along the axis of the associated roll and each lamina in a set having a corrugated profile with circumferentially spaced teeth, corresponding edges of the teeth of adjacent laminae being angularly displaced from one another about the axis of the associated roll, and the teeth of one set of laminae being arranged in mesh with the teeth of the other set of lamina, and the teeth of the laminae lying on helical paths extending around the associated roll and the element being formed by feeding sheet material between the rolls.

Further features of the invention will appear from the following description of various embodiments of the invention given by way of example only and with reference to the drawings in which:

*Figure 1* shows diagrammatically and in cross-section one arrangement of secondary surface element,

- Figure 2* is a section through a heat exchanger having secondary surface element similar to that of *Figure 1* taken on the line 2-2 in *Figure 3*,

*Figure 3* is a section on the line 3-3 in *Figure 2*,

- Figure 4* is a side elevation of part of another form of secondary surface element,

*Figure 4A* is an enlarged view of part of the element of *Figure 4*,

- Figure 5* is a cross-section on the line 5-5 in *Figure 4*,

- Figure 5A* is a cross-section on the line 5A-5A in *Figure 4A*,

*Figure 6* is a cross-section corresponding to that of *Figure 5* of part of a complete secondary surface element,

- Figure 7* is a perspective view of the element of *Figure 6* in combination with heat exchanger tubes,

*Figure 8* is a side elevation of apparatus for making the secondary surface elements of *Figures 4* to *7*, and

- Figure 9* is an enlarged view of part of the apparatus of *Figure 8*.

Referring to the drawings and firstly to *Figure 1*, a secondary surface element for heat exchangers is shown which is intended for use in a heat exchanger of the fin and tube kind, only the fin being shown in *Figure 1*.

- The fin of *Figure 1* has a leading edge portion 41 and a trailing edge portion 42 lying in a common plane. An intermediate portion 43 lies parallel to the leading edge and trailing edge portions 41, 42 but in a plane offset from the plane of these portions. Mutually inclined integral portions 44 and 45 join and are arranged symmetrically with respect to the portions 41, 42 and 43 to be of generally inverted V-shape with the apex of the V flattened at 43. It will be appreciated that a succession of inclined portions similar to those at 44 and 45 may be provided, extending in the direction indicated by the arrow A. This direction is also the direction in which heat exchange medium, for example air, flows to the fin

in its use in a heat exchanger.

The inclined portion 44 is formed with a set of louvres 46 extending between plane lateral edges of the fin, each of the louvres 46 making an acute angle to and intersecting the inclined portion 44. In this case the louvres 46 are also at an angle to the plane in which the portion 41 lies. The inclined portion 45 is also formed with a set of louvres 47 which are inclined in the opposite direction to the louvres 46. The louvres 47 are inclined to and intersect the portion 45 and also, in this case, the louvres 47 are inclined to the plane of the portion 42.

In the limiting case the angle of the louvres 46 and 47 relative to their respective inclined portions 44 and 45 may be such that the louvres are parallel to the planes of the portions 41 and 42.

Referring now to Figures 2 and 3, a secondary surface element or fin of the kind shown in Figure 1 may be incorporated in a heat exchanger of the fin and tube kind in the manner illustrated in Figures 2 and 3. In Figures 2 and 3 only one fin is illustrated but it will be appreciated that a large number of spaced apart and parallel fins will generally be employed.

The heat exchanger of Figures 2 and 3 has four rows of tubes 50, tubes in the second and fourth rows being offset with respect to those in the first and third rows. The tubes 50 pass through apertures in the fins which are in close contact with and secured, for example by solder, to the tube to give good heat transfer between the tubes and the secondary surface fins.

Each fin has a leading edge 51, a trailing edge 52 and an intermediate portion 53 parallel to but offset from the leading and trailing edges. Extending between and integral with the portions 51 and 53, and 53 and 52, are mutually inclined portions 54 and 55 respectively.

Sets of parallel louvres 56 are formed in the portion 54 between the tubes 50 of the first row and a tube 50 passes through the portion 54 downstream of the louvres 56 with respect to the direction of flow A.

Similar louvres 56A are formed in the portion 54 in between the tubes of the second row, as seen in Figure 3, which figure also indicates the lateral extent of the louvres and the unlouvered area of the portion 54. The louvres 56 and 56A are similarly arranged to the louvres 46 of Figure 1.

Sets of parallel louvres 57 are also formed in the inclined portion 55 laterally of and between the tubes 50 of the third row and further sets of louvres 57A are formed in the portion 55 between the tubes of the fourth row. The louvres 57 and 57A are inclined in the opposite direction to the louvres 56 and 56A. The louvres 57 and 57A are similarly arranged to the louvres 47 of Figure 1.

Air flow to the fin of Figures 2 and 3 is in the direction A and, in passing over the fin, the air passes from one side to the other of the fin through the louvres 56 and 56A and then back through the louvres 57 and 57A.

It will be seen that the fin of Figures 2 and 3 is of generally inverted V-shape having a flattened apex at 53, the louvres being formed in the mutually inclined flanks 54 and 55 of the V. A succession of

V-shaped portions may be formed along the air flow path. The arrangement of Figures 2 and 3 is in the general form of a fin and tube heat exchanger in which a heat exchange relationship is set up between a fluid passing through the tubes and a fluid passing over the fins.

Although in the arrangements of Figure 1 and Figures 2 and 3 there is provided intermediate portions 43 and 53 respectively, the inclined portions may be joined directly at the apex of the V. Similarly the leading and/or trailing ends of the inclined portions may constitute the leading and trailing edges by dispensing with the portions 41 and 42 and/or 51 and 52.

The louvred fin of Figure 1 and Figures 2 and 3 may be made from sheets of metal foil in which the louvres are formed in known manner, the louvred sheet being shaped by bending to the desired configuration, as described. The fin provides an improved air flow path over the fin because the louvres provide relatively large gaps without reducing the number of louvres present.

Referring now to Figures 4 to 9 and firstly to Figures 4, 4A, 5 and 5A, a secondary surface element is shown suitable for use sandwiched between heat exchanger tubes in the manner shown in Figure 7. The element of Figures 4, 4A, 5 and 5A is of corrugated form and is made from metal sheet or foil, the corrugations in this case being of truncated triangular form each with flat crests 17. It will, however, be appreciated that corrugations of other shapes can be formed, for example of generally sinusoidal shape or with relatively wider or narrower flat crests, provided that these are such that the material retains a unitary structure.

In Figures 4, 4A, 5 and 5A only three strips 11, 12 and 13 are shown as making up the element but it will be appreciated that a unitary sheet will normally have a greater number of strips.

Each of the strips 11, 12 and 13 is displaced from its adjacent strips by an amount  $d$  and the extent of the displacement  $d$  may be selected according to pitch  $P$  of the corrugations. The height of the secondary surface is given as  $h$ .

The flanks 15 of the corrugations are each inclined at an acute angle  $\alpha$  to the longitudinal direction of the strips. The angle  $\alpha$  is preferably in the range  $60^\circ$ - $80^\circ$ . The direction of displacement of the strips is opposite to the direction of inclination of the flanks 15. It will be appreciated that each strip 11, 12 and 13 has a leading and trailing edge, such as at 11a, 12a and 11b, 12b, having regard to a direction of flow A of fluid over the material which direction A is at a right angle to the longitudinal direction of the strips. Adjacent strips are interconnected at the crests 17 at 71a to form a unitary structure.

The displacement of adjacent strips from one another can be of any desired amount, ranging from a small displacement  $d$  by which the corrugations are aligned with one another in rows lying perpendicular to the longitudinal direction of the strips, to a larger displacement  $d$  of the order of a third the pitch  $P$  of the corrugations.

In use of the material in heat exchangers it is generally advantageous to maintain a large displace-

ment or gap between the leading edges 11a of the flanks 15 of the strips and the corresponding trailing edges 11b of the flanks of the preceding strips. At the same time the widths W of the strips should be kept narrow, but the achievement of these characteristics may have to be a compromise with the requirements of the manufacturing process.

Referring now to Figure 6 a complete secondary surface element is shown in which the direction of displacement *d* of the adjacent strips is reversed centrally of the element. At the same point in the strips as the reversal of displacement takes place the direction of inclination of the flanks of the corrugations is also reversed. The central strip 30 may be parallel to the general direction of flow A, as shown, or it may be of V-shaped profile, the limbs of the V lying parallel to the sets of strips to each side of the strip 30. As seen in Figure 6, the element is of symmetrical configuration about the strip 30 and this, together with the inclination of the flanks, enables the material to be readily formed, as will be described.

It will be appreciated that, with the material having corrugations of the kind described and shown, the free edges 11a, 11b of the strips can extend the full height *h* of the material. This compares with louvred material in which the louvres do not extend the full height but are formed along only a portion of the flanks of the corrugations.

Referring now particularly to Figure 7, the material of Figure 6 is assembled with tubes 31 so that an element is bounded on each side by a row of tubes 31. A heat exchange fluid is passed through the tubes 31 and a flow of further fluid, usually air, passes over the element in the general direction of arrows A to set up a heat exchange relationship between the two fluids. Alternatively the secondary surface element may be sandwiched between sheets in layers to form a cross-flow or a counter-flow heat exchanger.

Apparatus for forming the corrugated material of Figures 4-7 is shown in Figures 8 and 9 of the drawings and it comprises a pair of rolls 20 and 21 mounted on parallel shafts 22 and 23 for rotation in opposite directions, each roll being made up of laminae 24 arranged side by side in contact with one another and each lamina having an outer profile formed with circumferentially-spaced teeth 25. Adjacent laminae in each roll are angularly displaced from one another about the axis of the associated roll by a predetermined amount, as will be explained, and the teeth mesh together on rotation with a suitable space between them to receive the metal sheet or foil to be corrugated. The teeth 25 are helically arranged, that is, each tooth on each lamina lies along a helical path extending around the associated roll. This gives rise to the flanks of the teeth extending at an acute angle to lines parallel to the axis of the associated roll, which angle is the same for all the teeth so that the teeth may mesh with one another. Moreover, the helical paths on which the teeth of each lamina lie are equally spaced from one another circumferentially of the lamina.

One way of imagining the constructions of the rolls is to consider a pair of matching helical gear

wheels. Divide each gear wheel into a plurality of laminae along lines at right angles to the axes of the wheels and then displace each lamina a small amount angularly in relation to its next adjacent lamina in the opposite direction to the inclination of the flanks of the teeth and in a manner such that the gear wheels can mesh together. This results in a pair of rolls in accordance with the present invention and indeed the apparatus may be constructed generally as described. Alternatively helical teeth may be machined in an assembly of generally disc like laminae which are then angularly displaced from one another.

Upon feeding a sheet of heat-conducting material, for example metal sheet or foil, between these rolls, corrugated sheet material, such as shown in Figures 4-7 of the drawings, is formed. In this case the teeth 25 of the rolls are shaped to produce the truncated triangular corrugations shown.

## CLAIMS

1. A secondary surface element for a heat exchanger comprising sheet material formed with successive mutually inclined integral portions, each arranged to be inclined to the general direction of flow of heat exchange medium over the elements and the mutually inclined portions having louvres formed therein, each louvre lying in a plane inclined to the plane of the associated portion of the element.

2. A secondary surface element according to claim 1 wherein the sheet material is formed in successive V-shaped portions, the louvres being formed in the flanks of the V and lying in planes inclined to the flanks of the V.

3. A secondary surface element according to claim 2 wherein the apices of the V-shaped portions are flattened to provide portions which are arranged to be generally parallel to said general direction of flow of the heat exchange medium.

4. A secondary surface element according to claim 2 or 3 wherein the planes of the louvres in one flank of each V-shaped portion are oppositely inclined to the planes of the louvres of the other flank.

5. A secondary surface element according to any one of claims 2, 3 or 4 wherein ends of the V-shaped portions are integral with portions lying generally parallel to the general direction of flow of heat exchange medium over the element.

6. A secondary surface element according to any one of the preceding claims having a plurality of apertures for receiving tubes so that the tubes extend through the element generally perpendicular to said direction of flow of heat exchange medium over the elements.

7. A secondary surface element according to any one of the preceding claims wherein the louvres are formed in sets there being two or more sets formed in each inclined portion and spaced from one another.

8. A secondary surface element according to claim 7, as appendent to claim 6, wherein the apertures are formed in the element between the sets of louvres.

9. A secondary surface element for a heat ex-



changer comprising corrugated sheet material formed of a plurality of corrugated strips, each strip being similarly shaped and corresponding portions of the flanks of the corrugations in adjacent strips  
5 being displaced from one another in the longitudinal direction of the strips whereby the leading edge of each flank is displaced in one direction from the trailing edge of the corresponding flank of an immediately adjacent strip, the strips being joined to  
10 one another to form a unitary structure, and the flanks of the corrugations each being inclined in the opposite direction to said displacement at an acute angle to the longitudinal direction of the strips.

10. A secondary surface element according to  
15 claim 9 wherein the direction of displacement of the edges of the strips is reversed across the element to provide at least two groups of strips, the displacement of the edges of each group being in opposite directions to one another and the direction of  
20 inclination of the flanks of each group being opposite to the direction of displacement of the strips of that group.

11. A secondary surface element according to claim 10 wherein the element is arranged symmetrically about a central longitudinal strip.  
25

12. A secondary surface element according to any one of claims 9 to 11 wherein the angle of the flanks of the corrugations to the longitudinal direction of the strips is in the range 60°-80°.

30 13. A secondary surface element according to any one of claims 9 to 12 wherein the displacement between the leading edges and the trailing edges of adjacent strips is such that the corrugations are in alignment in a direction at a right angle to the  
35 longitudinal direction of the strips.

14. A secondary surface element according to any one of claims 9 to 13 wherein the displacement between the leading edges and the trailing edges of adjacent strips is of the order of one third the pitch of  
40 the corrugations.

15. A secondary surface element according to any one of claims 9 to 14 wherein the element is arranged to have the crests of the corrugations in contact with heat exchange tubes and a flow of heat  
45 exchange medium over the element is in a direction at right angles to the longitudinal direction of the strips.

16. Apparatus for forming a secondary surface element according to any one of claims 9 to 15  
50 comprising a pair of rolls and drive means for driving at least one of the rolls so that the rolls rotate in opposite directions, each roll being formed of a set of laminae arranged side by side along the axis of the associated roll and each lamina in a set having a  
55 corrugated profile with circumferentially spaced teeth, corresponding edges of the teeth of adjacent laminae being angularly displaced from one another about the axis of the associated roll, and the teeth of one set of laminae being arranged in mesh with the  
60 teeth of the other set of laminae, and the teeth of the laminae lying on helical paths extending around the associated roll, and the element being formed by feeding sheet material between the rolls.

17. A secondary surface element for a heat  
65 exchanger substantially as described with reference

to Figure 1 or Figures 2 and 3.

18. A secondary surface element for a heat exchanger substantially as described with reference to Figures 4, 4A, 5, 5A, 6 and 7 of the drawings.

70 19. Apparatus for forming secondary surface elements of heat exchanger substantially as described with reference to Figures 8 and 9 of the drawings.

Printed for Her Majesty's Stationery Office by Croydon Printing Company Limited, Croydon Surrey, 1980.  
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY; from which copies may be obtained.